Jet Propulsion Laboratory
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Mid-Wave and Long-Wave Infrared T2SLS Digital Focal Planes for Earth Remote Sensing Instruments

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Problem to Solve

Many infrared (IR) remote sensing instruments rely on high performance IR detectors (i.e., photon) which requires active cryogenic cooling

- Cryocoolers significantly increase the Size, Weight, and Power (SWaP) of the remote sensing instruments
- Heat from the cryocooler expander & compressor need to be removed efficiently via a radiator (i.e., thermal management)
- Radiator need to be align properly during on orbit operation (i.e., operational management)
- Cryocoolers need significant amount of power (i.e., power management)
- These issues frequently prevent implementation of sensitive IR remote sensing instrument into SmallSats such as 6U CubeSat busses

Our Approach to Solve the Problem

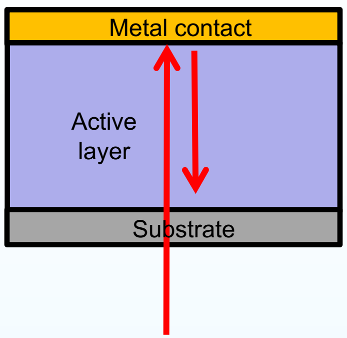
- Barrier Infrared Detectors (BIRDs) technology
  - Decrease detector dark current (i.e., reduce noise -> increase SNR)
- Resonator Pixel (RP) light coupling technology
  - Increase detector quantum efficiency (i.e., increase SNR)
- Metasurface based flatlens technology
  - Decrease dark current (i.e., increase SNR)
- 3D-Digital read out integrated circuits (DROICs) technology
  - Increases the ROIC well depth (i.e., reduce noise -> increase SNR)
- Digital RP-BIRD focal plane arrays
  - Increases SNR or increases operating temperature for same SNR
  - Reduce the Size, Weight, and Power (SWaP) factor of the Integrated Detector Dewar Cooler Assembly (IDDCA) -> Enables SmallSat applications
  - Digital RP-BIRD MWIR at 200K & LWIR at 100K for broadband imaging
  - SF-400: 2W, 100W, 3.8Kg whereas SF-070: 800mW, 40W, 0.85Kg

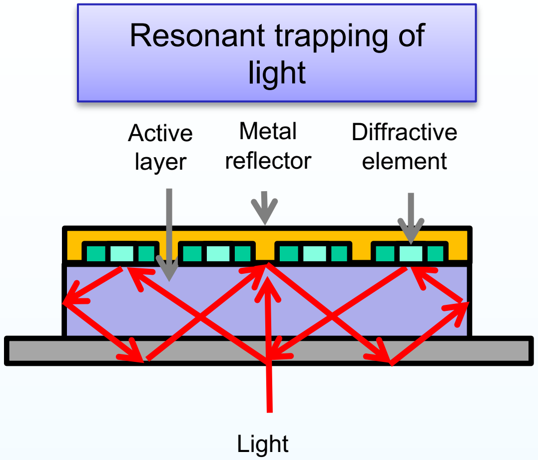
SF-400

SF-070

Metasurfaced Resonator-Pixel

Classical Detector





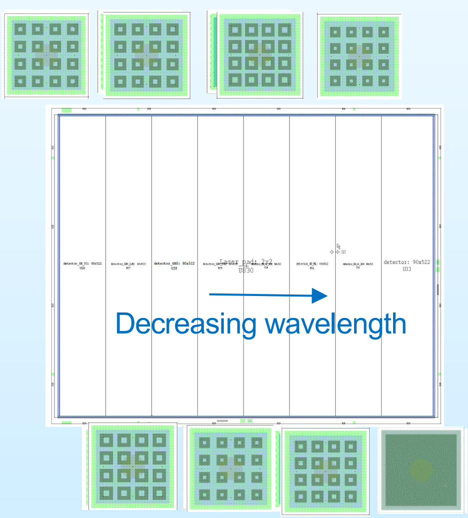
Concept:

Diffract incident light at an angle larger than the **critical angle** of total internal reflection to achieve three-dimensional optical confinement

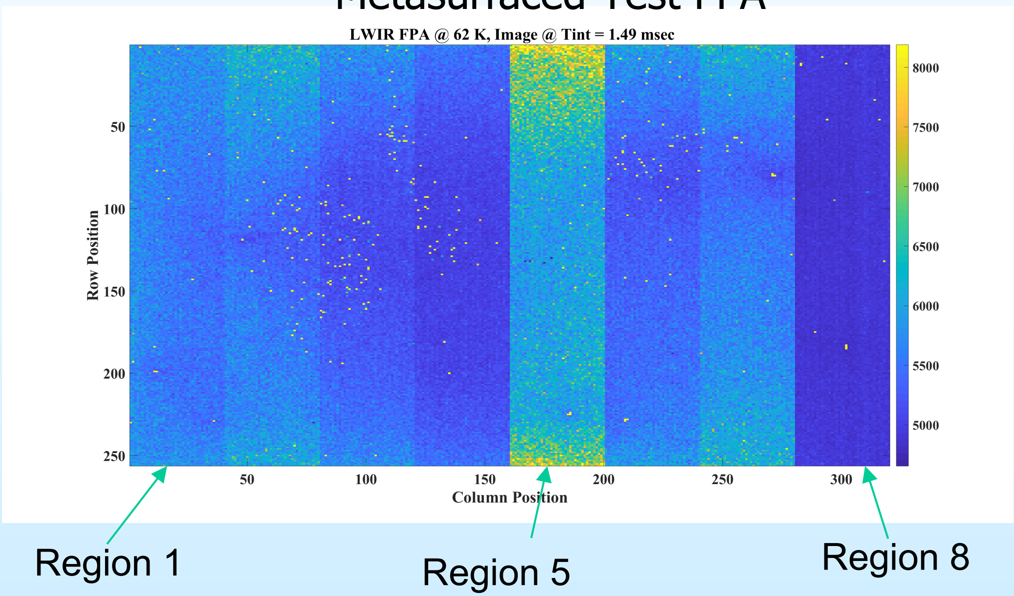
Advantages:

- Increases quantum efficiency
- Thin active layers (good for low carrier mobility)
- Low dark current (due to thin pixel)
- Free of anti-reflection coating

8 different designs for 40x256 stripes on the array

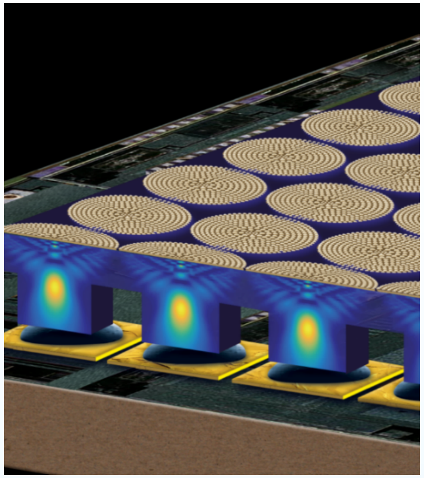


Metasurfaced Test FPA



Integrating GaSb metalenses with photodetectors

- Each FPA pixel is monolithically integrated with optical concentrator based on flat metalens. Metalenses are fabricated on the backside of the FPA
- Shrink pixel size to reduce dark current, but keep the same optical area using flat metalens
- Fabrication is done by e-beam lithography and chlorine and fluorine plasma etching to define the nano-pillars
- We expect to keep the same optical area and up to 25K increase in operating temperature



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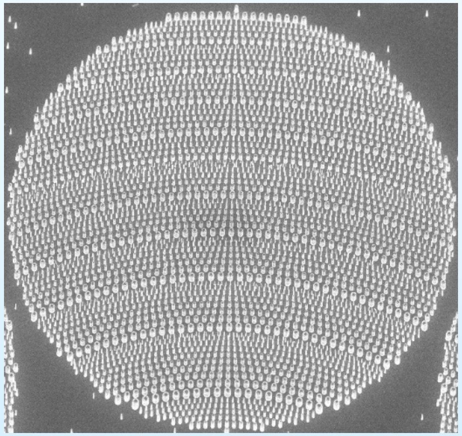
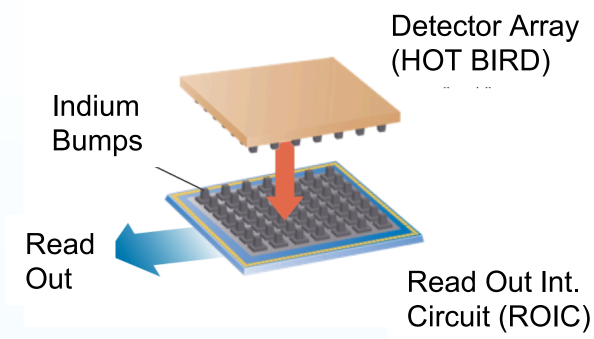
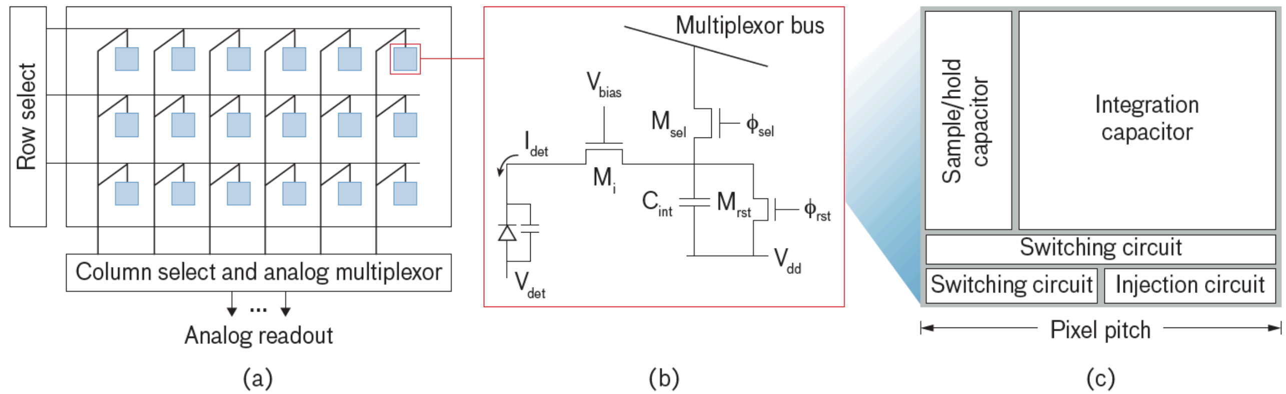


Scanning electron microscope image of a GaSb metalens on the substrate side of a MWIR HOT-BIRD pixel

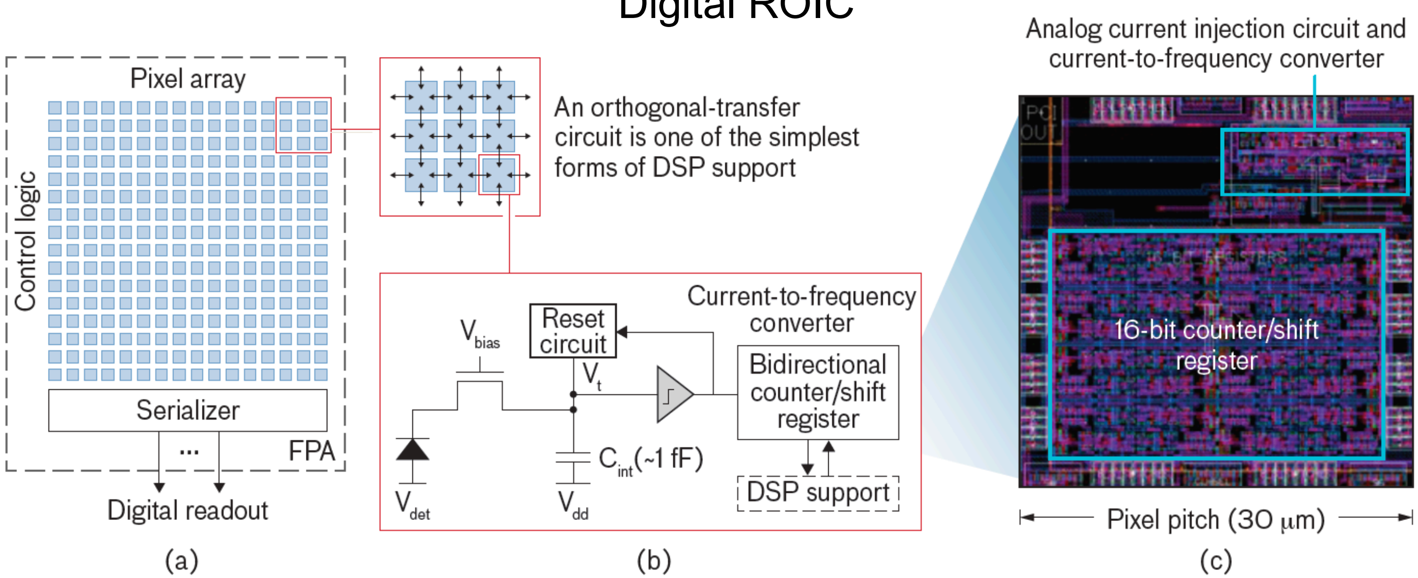
Digital Read Out Integrated Circuits (DROICs)



Analog ROIC



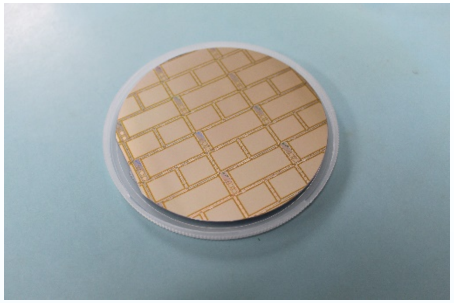
Digital ROIC



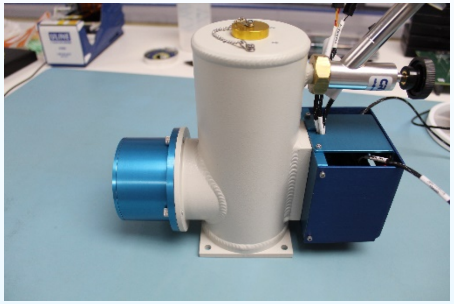
Ref: Kenneth I. Schultz, *et al.*, "Digital-Pixel Focal Plane Array Technology", Lincoln Laboratory Journal, Vol. 20, Number 2 (2014).

Case Study: Digital BIRD FPA for Land Imaging to Meet New Challenges (Imager)

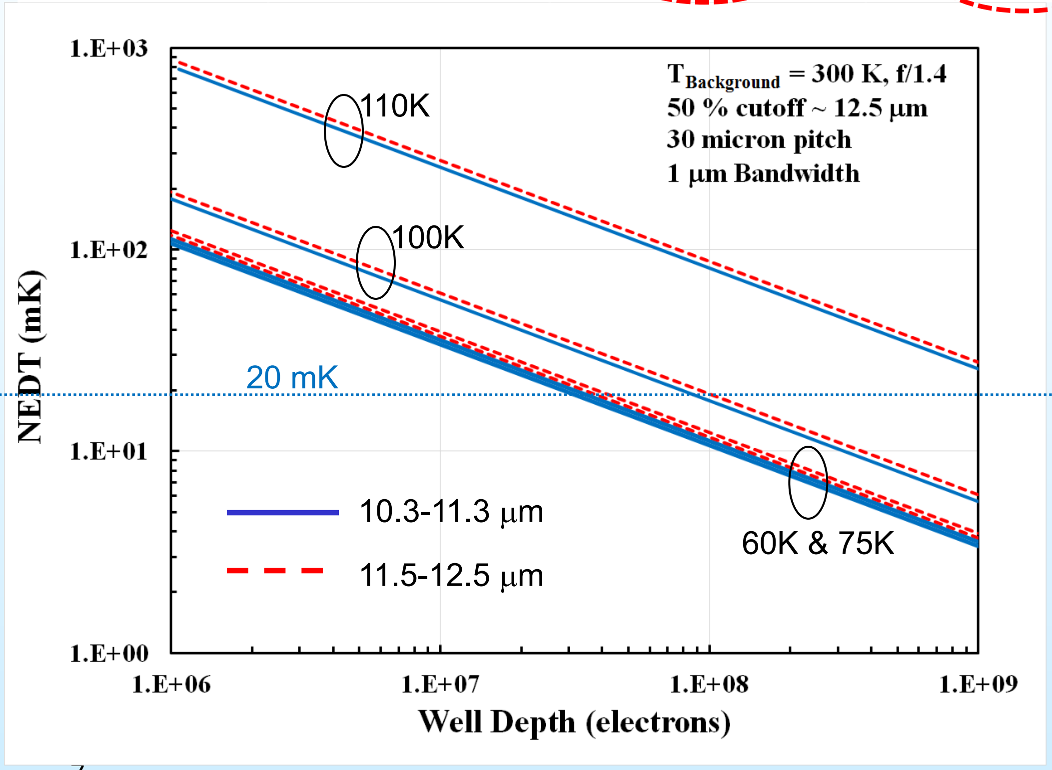
ROIC	ISC-9803 AROIC	DRS 3D-DROIC	Copious DROIC
Binning	1 × 1	1 × 1	1x1
ROIC Format	640 × 512	2004 × 2008	640x480
Pixel Pitch	25 µm	8 µm	20 µm
Well Depth	11 Me^-	173 Me^-	229 Me^-



Cored DROIC Wafers



DROIC Test Station



$$\boxed{SNR_{Max} = \frac{Signal_{Max}}{Noise} = \sqrt{Well\ Depth_{Max}}}$$

- BIRD for improved detector dark current and QE performance over QWIP (i.e., 43K)
- Digital-pixel ROIC with large well depth enables much longer integration time to improve signal to noise ratio

Summary

- Recent advances in HOT Barrier IR Detector (BIRD) technology is a breakthrough
  - Elevated the FPA operating temperature, good uniformity & operability, and good manufacturability
- Resonator Pixel technology
  - No net effect on SNR
- Metasurface based flatlens technology
  - Increase SNR by x3
- Digital ROIC is a breakthrough technology
  - Elevates operating temperature

- RP-BIRD DFPA elevates the operating temperature of FPAs
  - Lowers the SWaP factor
  - Enables the low cost Cubesats & Smallsats (for IR land imaging, Spectrometers, and sounders)
  - 200K for MWIR and 100K for LWIR for broadband land imaging
- This work is sponsored by NASA ESTO under ACT program